Michigan Tech

Ground-Based Profiling Radar Applications for Spaceborne Snowfall Retrievals

Mark Kulie[1,*], Claire Pettersen[2], William Hahn[2], Tim Wagner[2], Tristan L'Ecuyer[2], Larry Bliven[3], David Wolff[3], Walt Petersen[4]

[1]Michigan Technological University, Houghton, MI, [2]University of Wisconsin-Madison, Madison, WI, [3]NASA WFF, [4]NASA MSFC

*Contact Information: mkulie@mtu.edu

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I. Profiling Radar Datasets

Ground-based profiling radars offer unique observational capabilities that can be exploited for Global Precipitation Measurement (GPM) mission snowfall retrieval applications. Profiling radars provide scientifically useful long-term datasets associated with snowfall events, serve as excellent GPM evaluation datasets, and provide valuable guidance for future spaceborne radar missions. Two profiling radar datasets are used for snowfall radar retrieval applications (**Figs. 1 and 2**).

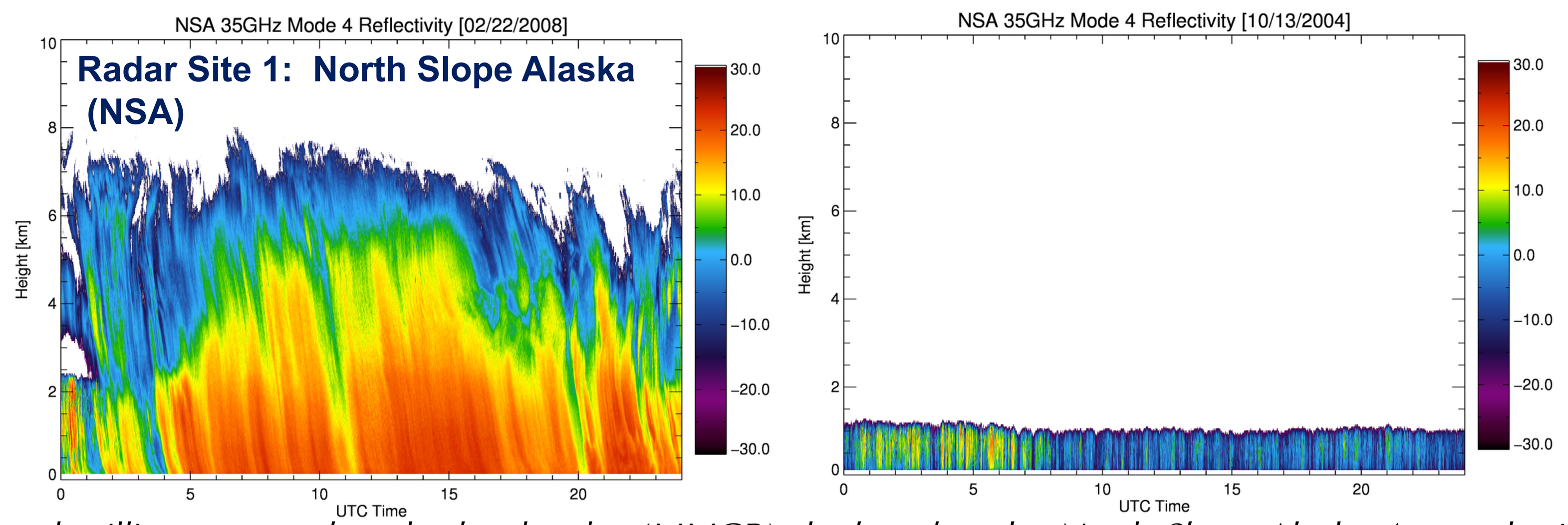

FIG. 1: Ka-band millimeter wavelength cloud radar (MMCR) deployed at the North Slope Alaska Atmospheric Radiation Measurement Climate Research Facility. MMCR observations for 22 Feb 2008 (left) and 13 Oct 2004 (right) respectively illustrate synoptic/frontal deep and boundary-layer shallow convective snow events.

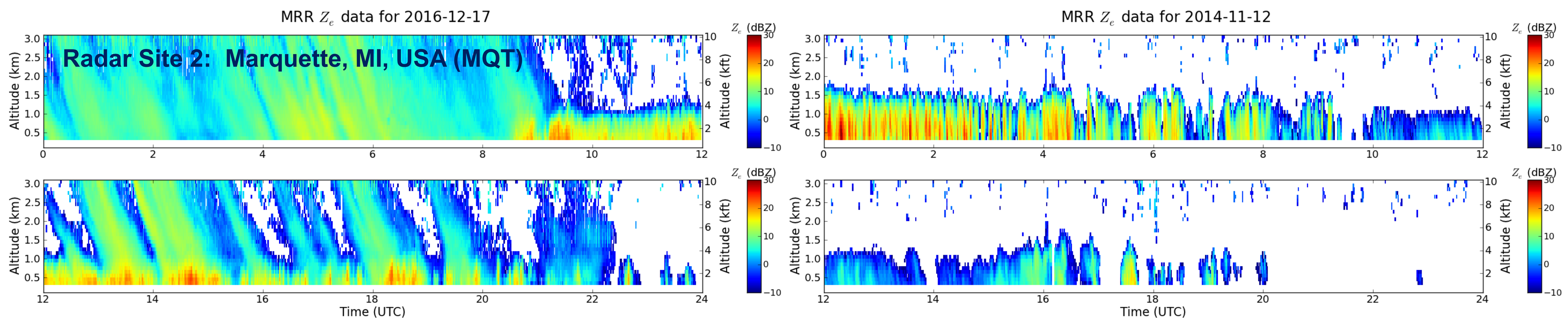

FIG. 2: A Ka-band Micro Rain Radar (MRR) has been deployed at the Marquette, MI National Weather Service Weather Forecast Office since January 2014. MRR observations for 17 Dec 2016 (left) illustrate synoptic/frontal deep snow (0000-0900 UTC), shallow orographic snow (0900-1200 UTC), and orographically enhanced synoptic snow (near 0900 UTC and intermittently between 1200-2200 UTC). MRR observations for 12 Nov 2014 (right) show convective boundary layer lake-effect snow showers.

- Snowfall modes discernible from profiling radars (**Figs. 1 and 2**):
  - I. Synoptic/frontal snow
  - II. Shallow convective snow (e.g., lake-effect and/or Arctic stratocumulus)
  - III. Orographic
  - IV. Embedded orographic or lake-effect within synoptic/frontal
- Extreme particle growth in lowest 0.5-1.0 km AGL complicates spaceborne retrievals (**Fig. 2**)
- Snowfall mode variability and mixed snowfall modes in aggregate reflectivity analyses (**Figs. 3 and 4**)
- NSA: Distinct snowfall mode interannual variability (**Fig. 3**)
- MQT: Extremely shallow snowfall modes like lake-effect and orographic commonly occur (**Fig. 4**)
- Shallow, light snowfall events create difficult snowfall retrieval situations for GPM DPR (**Figs. 3 and 4**)

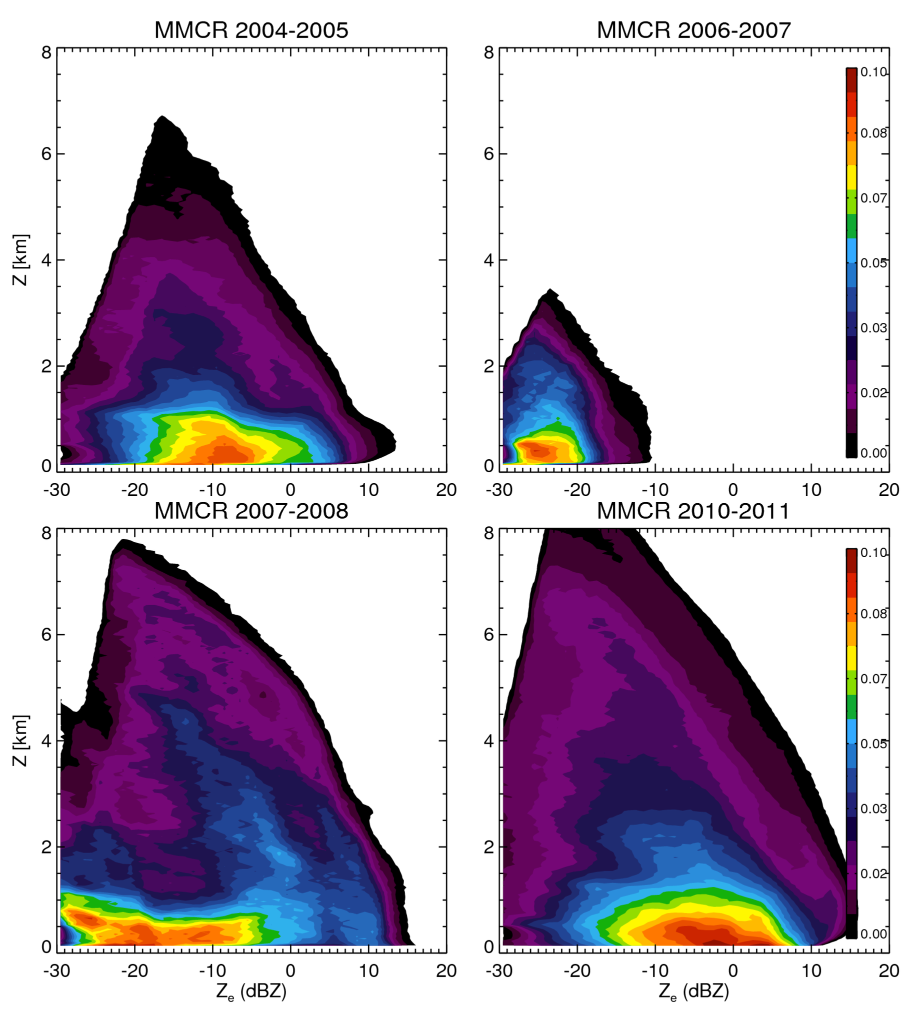

FIG. 3: MMCR reflectivity/height normalized occurrence 2D histograms for select winter seasons.

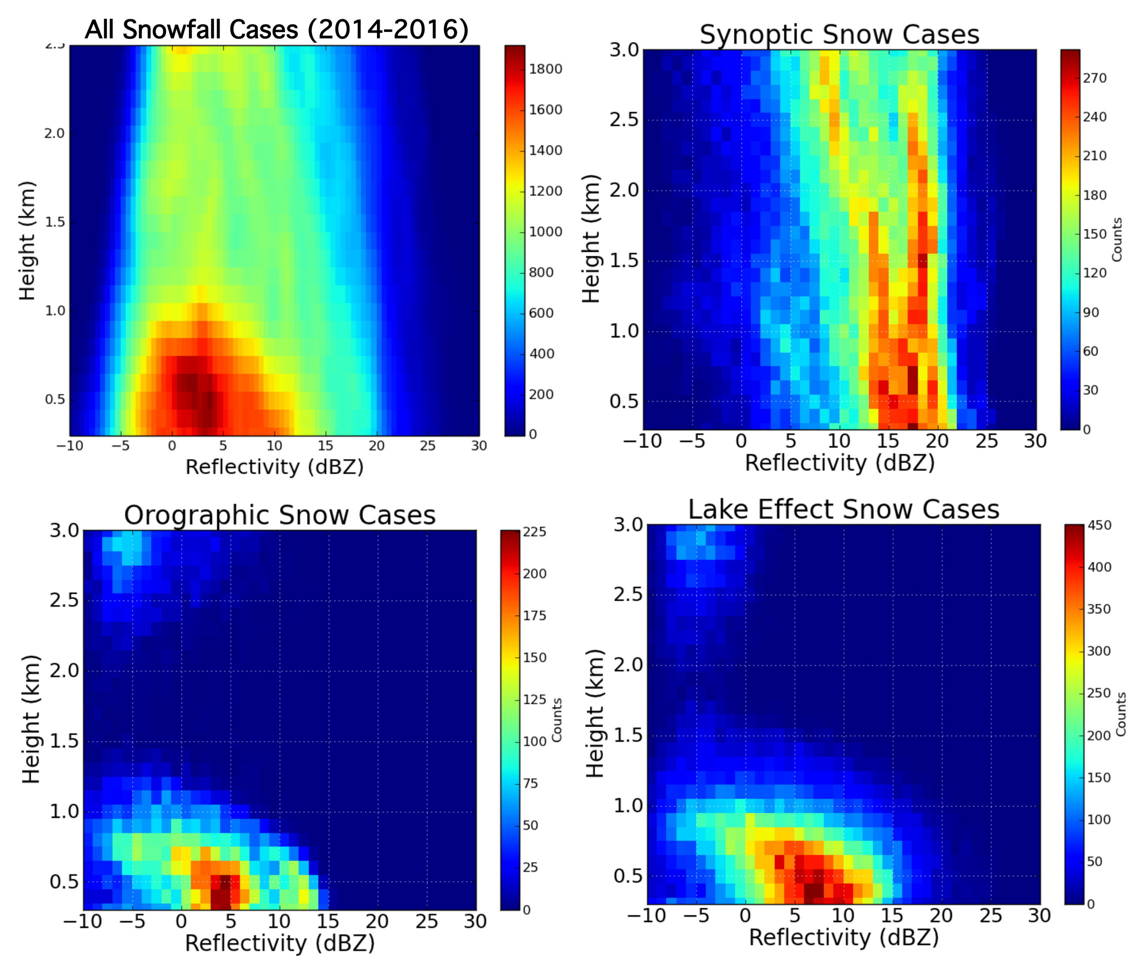

FIG. 4: MQT MRR reflectivity/height occurrence 2D histograms for all snowfall cases in the 2014-2016 dataset (top left) and for a subset of synoptic (top right), orographic (bottom left), and lake-effect (bottom right) snowfall cases

II. Spaceborne Radar Snowfall Retrieval Applications

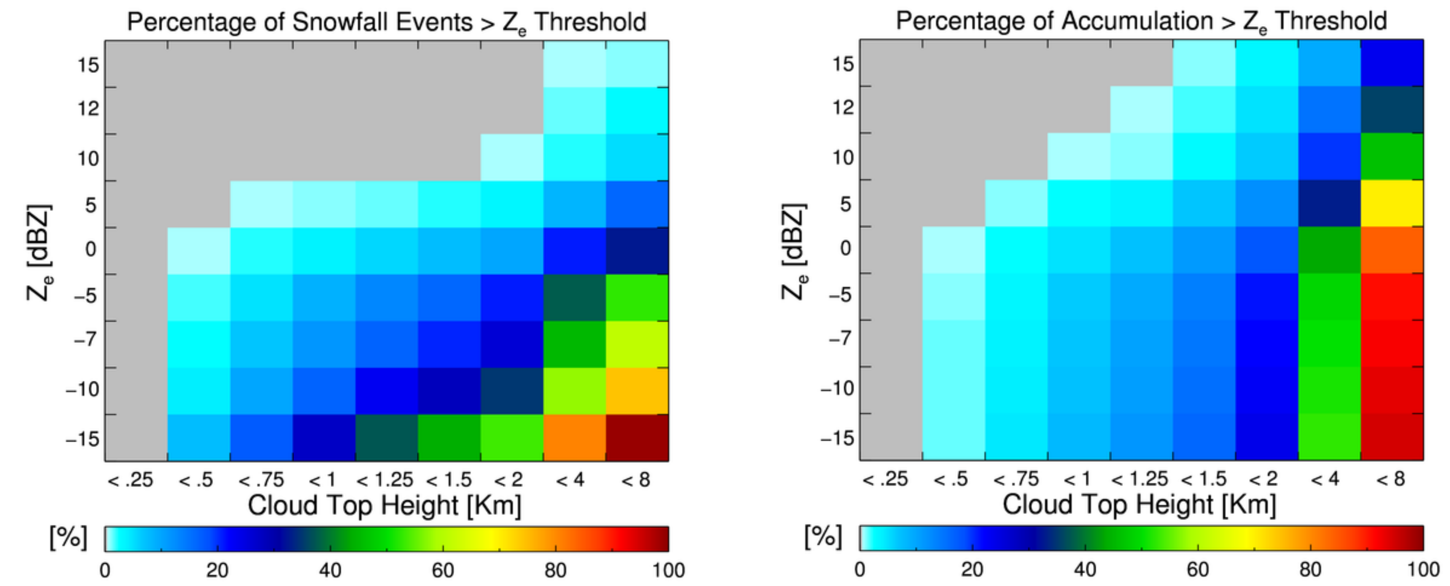

FIG. 5: Percentage of snowfall events (left) and estimated snowfall accumulation (right) within various radar reflectivity and cloud top height thresholds for the 2004-2011 MMCR snowfall dataset.

Spaceborne radar snowfall retrieval efficacy

- Radar sensitivity thresholds as functions of MMCR-derived cloud top height (**Figs. 5 and 6**)
- Assumptions:
  - I. -15 dBZ lower threshold applied to MMCR dataset to mimic common spaceborne radar precipitation threshold
  - II. Matrosov et al. (2007) 35 GHz Z-S relationship for snowfall accumulation statistics (no snowfall mode dependence)
- Useful statistics for high-latitude locations
  - I. Percentage of snowfall events/accumulation missed by current and future proposed sensors
  - II. Guidance for future spaceborne radar development
- Interannual and monthly variability at NSA site (**Fig. 6**)

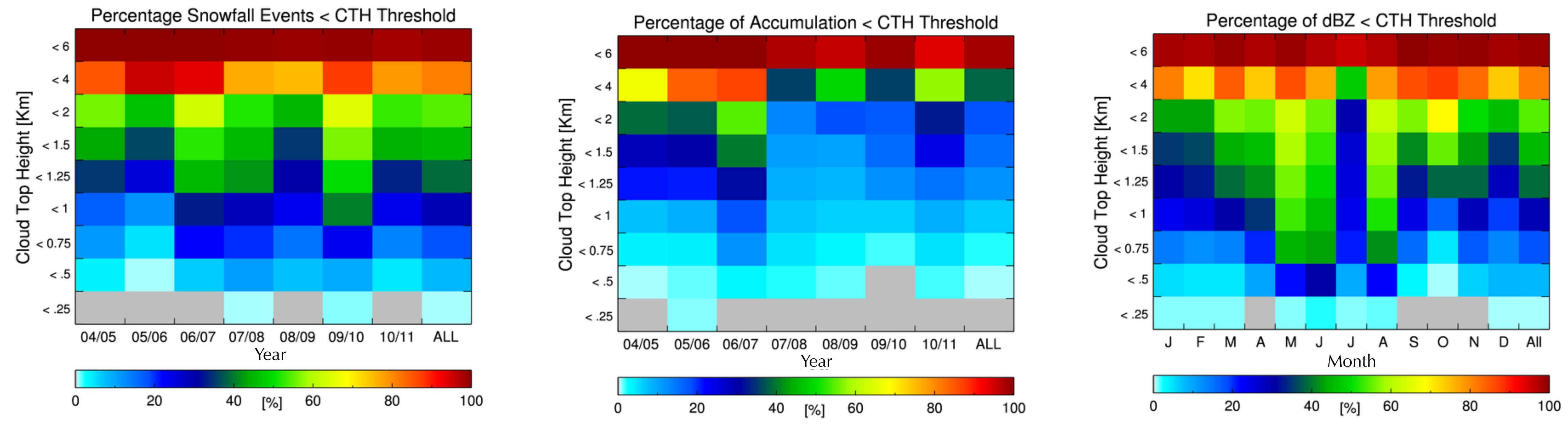

FIG. 6: Percentage of annual snowfall events (left), annual estimated snowfall accumulation (center), and monthly snowfall events (right) within various cloud top height thresholds for the 2004-2011 MMCR snowfall dataset.

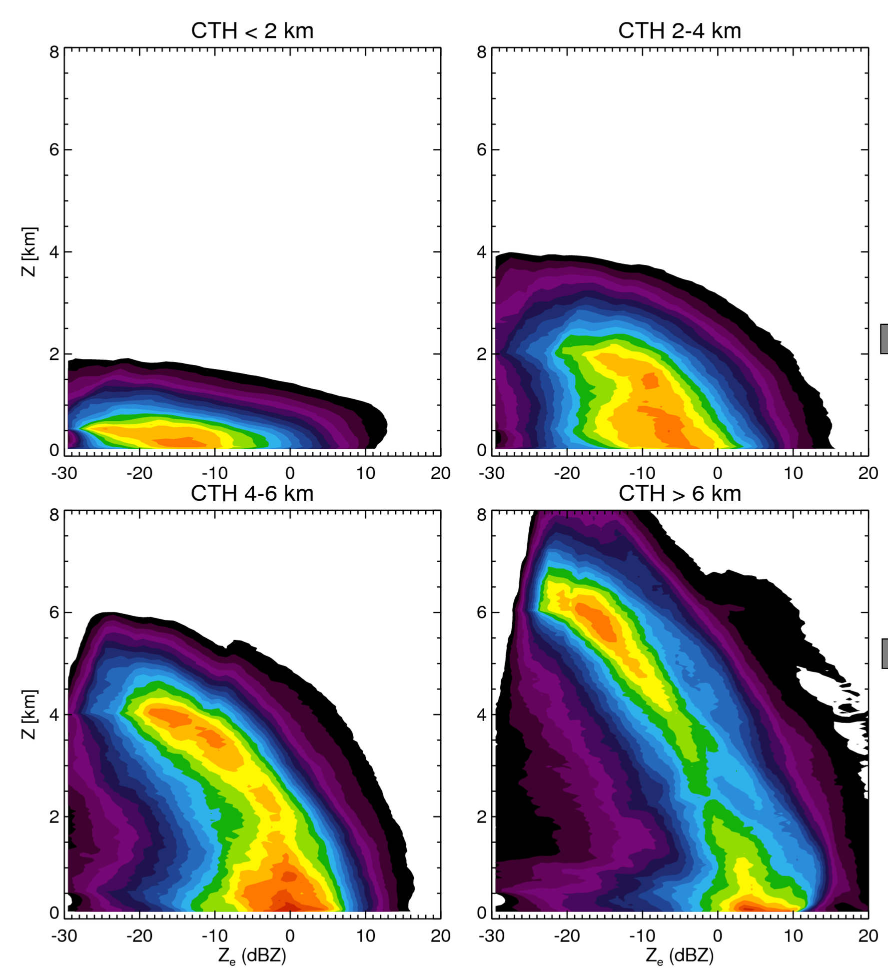

FIG. 7: MMCR reflectivity/height normalized occurrence 2D histograms based on four cloud top height categories.

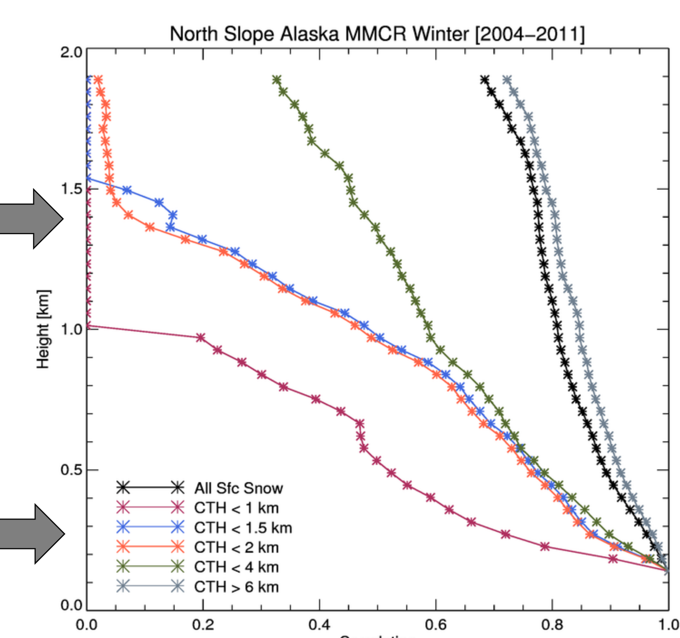

FIG. 8: MMCR correlation between the lowest usable radar bin and various height bins for different snow-producing cloud regimes.

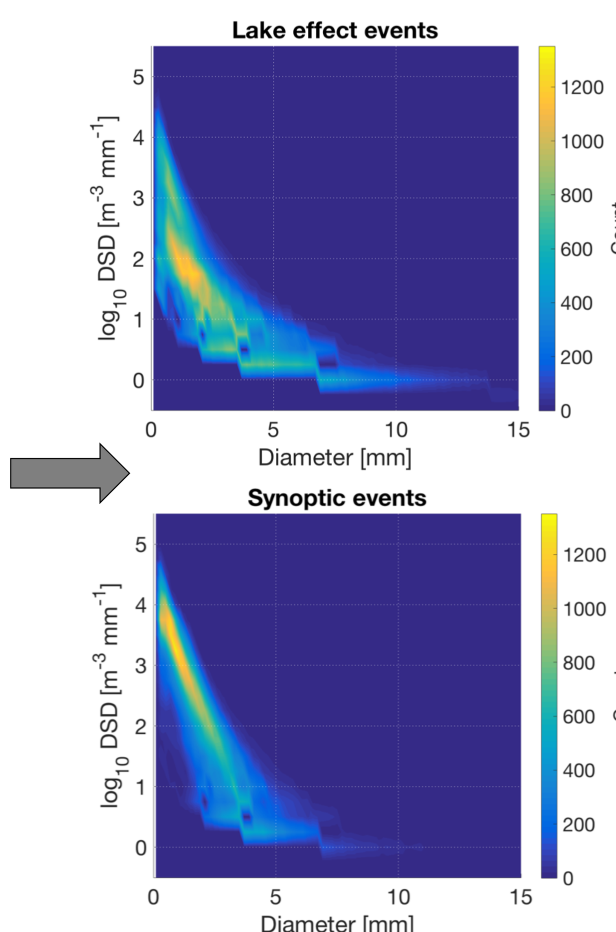

FIG. 9: MQT particle size distributions for lake-effect (top) and synoptic/frontal (bottom) snow events measured by the NASA Precipitation Imaging Package optical disdrometer.

Snowfall modes present unique retrieval challenges

- I. Radar blind zone and near-surface bin designation (growth, decay, stable in lowest levels?) (**Fig. 7**)
- II. Is near-surface bin used for snowfall rate retrievals correlated to actual surface snowfall? (**Fig. 8**)
- III. Snow microphysical properties can change drastically in different snowfall types (**Fig. 9**)